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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-686

WIND-TUNNEL INVESTIGATION OF THE STATIC LONGITUDINAL
AERODYNAMIC CHARACTERISTICS OF A MODIFIED MODEL OF
A PROPOSED APOLLO ATMOSPHERIC-ABORT CONFIGURATION
AT MACH NUMBERS FROM 0.30 TO 1.20*

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SUMMARY

An investigation has been conducted in the Langley 8-foot transonic pressure tunnel to determine the static longitudinal aerodynamic characteristics of a modified model of a proposed Apollo atmospheric-abort configuration. The modifications consisted of increasing the fineness ratio of the abort rocket, changing the half-cone angle of the spacecraft from 35° to 33° , and adding a fairing around the abort rocket nozzles. The investigation was conducted at angles of attack from about -1° to 50° at test Reynolds numbers, based on maximum body diameter and free-stream conditions, from about 1.64×10^6 to 3.83×10^6 .

The results of this investigation have shown that the model without the abort-rocket-nozzle fairing does not trim at any test angle of attack and is generally unstable about the center of gravity of this investigation. Increasing the fineness ratio of the abort rocket in conjunction with decreasing the half-cone angle of the spacecraft has no effect on the model stability. Addition of the abort-rocket-nozzle fairing has a stabilizing effect on the model at Mach numbers greater than about 0.65, increases the slope of the normal-force curve, and decreases the axial-force coefficient at an angle of attack of approximately 0° .

INTRODUCTION

The static longitudinal aerodynamic characteristics of models of reentry and atmospheric-abort configurations of a proposed Apollo spacecraft are given in reference 1 for Mach numbers from 0.30 to 1.20. The

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data of this reference show that the atmospheric-abort configuration is unstable below a Mach number of about 0.60 and is marginally stable at the higher test Mach numbers. In an attempt to improve the stability and thus reduce the amount of ballast required to stabilize the configuration, the abort rocket has been redesigned to increase the fineness ratio. In addition, the half-cone angle of the spacecraft has been changed from 35° to 33° in order to increase the volume available for instrumentation. Additional wind-tunnel tests made at supersonic speeds (ref. 2) show that the model stability near a Mach number of 1.57 is affected by unsteady flow oscillations which originate from the nozzles at the base of the abort rocket. The use of a fairing over the abort rocket nozzles has been proposed to eliminate these unsteady flow oscillations and thus improve the static longitudinal stability at this Mach number of 1.57.

The present investigation was performed in the Langley 8-foot transonic pressure tunnel and provides static aerodynamic data at subsonic and transonic speeds for a model of the atmospheric-abort configuration incorporating the aforementioned modifications at angles of attack to a maximum of about 50° . In addition, tests were made with the nozzle fairing removed. The tests were conducted at Mach numbers from 0.30 to 1.20 and at Reynolds numbers, based on maximum body diameter and free-stream conditions, which varied from about 1.64×10^6 to 3.83×10^6 .

SYMBOLS

The data presented herein are referred to the body system of axes with the origin located at the center of gravity. The positive direction of forces, moments, and displacements are shown in figure 1. The coefficients and symbols are defined as follows:

A	maximum cross-sectional area, 0.6504 sq ft
C_A	axial-force coefficient, $\frac{\text{Axial force}}{qA}$
$C_{A, \alpha \approx 0}$	axial-force coefficient at $\alpha \approx 0$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$
$C_{m\alpha}$	slope of pitching-moment curve at $\alpha \approx 0$, $\partial C_m / \partial \alpha$, per deg
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qA}$

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$C_{N\alpha}$	slope of normal-force curve at $\alpha \approx 0$, $\partial C_N / \partial \alpha$, per deg
$C_{p,c}$	model chamber-pressure coefficient, $\frac{\text{Model chamber pressure} - \text{Free-stream static pressure}}{q}$
D	diameter, in.
d	maximum body diameter, 10.920 in.
M	free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
R	Reynolds number based on maximum body diameter and free-stream conditions
r	radius, in.
x	distance from model base to center of gravity, in.
z	distance from model center line to center of gravity, in.
α	angle of attack of model center line, deg

MODELS, TESTS, AND ACCURACY

Details of the 0.06825-scale model and components tested are shown in figure 2 and photographs are presented in figure 3. The conical spacecraft portion of the model was made from the aluminum-alloy model of reference 1 with the half-angle changed to 33° by bonding plaster to the surface. The abort system was composed of a cylindrical aluminum-alloy body simulating a rocket container mounted on a tower made from three cross-braced steel rods. The three rods were located 120° apart and were oriented so that the two lower rods were in a horizontal plane when the model was near an angle of attack of 0° .

The model was mounted on a three-component internally located strain-gage balance which was sting supported. Two model—sting-support arrangements were used in order to obtain a large angle-of-attack range and also to maintain the model near the tunnel center line throughout this range. (See fig. 3.)

The tests were conducted in the Langley 8-foot transonic pressure tunnel at a stagnation temperature of about 121°F and at a stagnation pressure which was varied from about 1.0 atmosphere to 0.6 atmosphere due to load limits on the strain-gage balance. The variation of Reynolds number, based on model maximum diameter and free-stream conditions, with Mach number is shown in figure 4. The model was tested at Mach numbers from 0.30 to 1.20 at angles of attack from about -1° to 50° .

Normal force, axial force, and pitching moment were determined by means of the strain-gage balance with the pitching moments referred to the center-of-gravity location shown in figure 2. The axial-force results presented herein are gross values and have not been adjusted to a condition of free-stream static pressure at the model base. The model chamber pressure was measured by means of an orifice located inside the model in the strain-gage balance chamber.

Based upon balance accuracy (neglecting any sting interference effects), it is estimated that the coefficients of normal force, axial force, and pitching moment are accurate within ± 0.043 , ± 0.043 , and ± 0.0085 , respectively, at a Mach number of 0.30. This accuracy improves at the higher Mach numbers and dynamic pressures. All data presented from this investigation are essentially free of wall-reflected disturbances. The maximum variation of the actual test Mach number from the presented nominal values is less than ± 0.005 . Corrections were applied for tunnel flow angularity and for structural deflections of the model sting and balance. The accuracy of the angle of attack is estimated to be within $\pm 0.20^{\circ}$.

RESULTS AND DISCUSSION

The pitching-moment, normal-force, axial-force, and chamber-pressure coefficients for the model with and without the abort-rocket-nozzle fairing attached are presented in figure 5 and summarized in figure 6. A comparison of the stability characteristics of the model to the model of reference 1 is shown in figure 7.

At angles of attack near 25° some interference effects due to the different sting-support arrangements are indicated. These effects are similar to those reported in reference 3 for a Mercury exit configuration in that they are negligible on the pitching-moment and axial-force characteristics (figs. 5(a) and 5(c)) but are more pronounced on the normal-force characteristics (fig. 5(b)). These sting-support interference effects for the present investigation decrease with increasing Mach number; the difference between the measured and average faired values amounts to about 9 percent at a Mach number of 0.30 but is only approximately 2 percent at a Mach number of 1.20.

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The results of the present investigation show that the model does not trim at any test angle of attack (fig. 5) and without the nozzle fairing is generally unstable about the center of gravity of this investigation (fig. 6). Addition of the abort-rocket-nozzle fairing has a stabilizing effect on the model at Mach numbers greater than about 0.65 for angles of attack near 0° .

The pitching-moment results of figures 5 and 6 are referred to a center of gravity located at $\frac{x}{d} = 0.390$ and $\frac{z}{d} = 0.0473$ but in figure 7 are referred to a center of gravity along the center line at $\frac{x}{d} = 0.426$ from the model base for comparison with data from reference 1 (center of gravity on model center line at $\frac{x}{d} = 0.426$). This comparison indicates that the increased fineness ratio of the abort rocket and the decreased half-cone angle have essentially no effect on the model static stability.

Addition of the nozzle fairing increases C_{N_α} throughout the Mach number range of the investigation (fig. 6) but decreases $C_{A, \alpha=0}$ by as much as 22 percent at a Mach number of 1.20.

CONCLUDING REMARKS

Wind-tunnel tests of a modified model of a proposed Apollo atmospheric-abort configuration, conducted in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.30 to 1.20, have shown that the model without the nozzle fairing does not trim at any test angle of attack and is generally unstable about the center of gravity of this investigation. Increasing the fineness ratio of the abort rocket in conjunction with decreasing the half-cone angle of the spacecraft has essentially no effect on the model stability. Addition of the abort-rocket-nozzle fairing has a stabilizing effect on the model at Mach numbers greater than about 0.65, increases the slope of the normal-force curve and decreases the axial-force coefficient at an angle of attack of approximately 0° .

Langley Research Center,
National Aeronautics and Space Administration,
Langley Air Force Base, Va., March 2, 1962.

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REFERENCES

1. Pearson, Albin O.: Wind-Tunnel Investigation of the Static Longitudinal Aerodynamic Characteristics of Models of Reentry and Atmospheric-Absort Configurations of a Proposed Apollo Spacecraft at Mach Numbers from 0.30 to 1.20. NASA TM X-604, 1961.
2. Morgan, James R., and Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a 0.07-Scale Model of a Proposed Apollo Spacecraft at Mach Numbers of 1.57 to 4.65. NASA TM X-603, 1961.
3. Pearson, Albin O.: Wind-Tunnel Investigation at Mach Numbers from 0.50 to 1.14 of the Static Aerodynamic Characteristics of a Model of a Project Mercury Capsule. NASA TM X-292, 1960.

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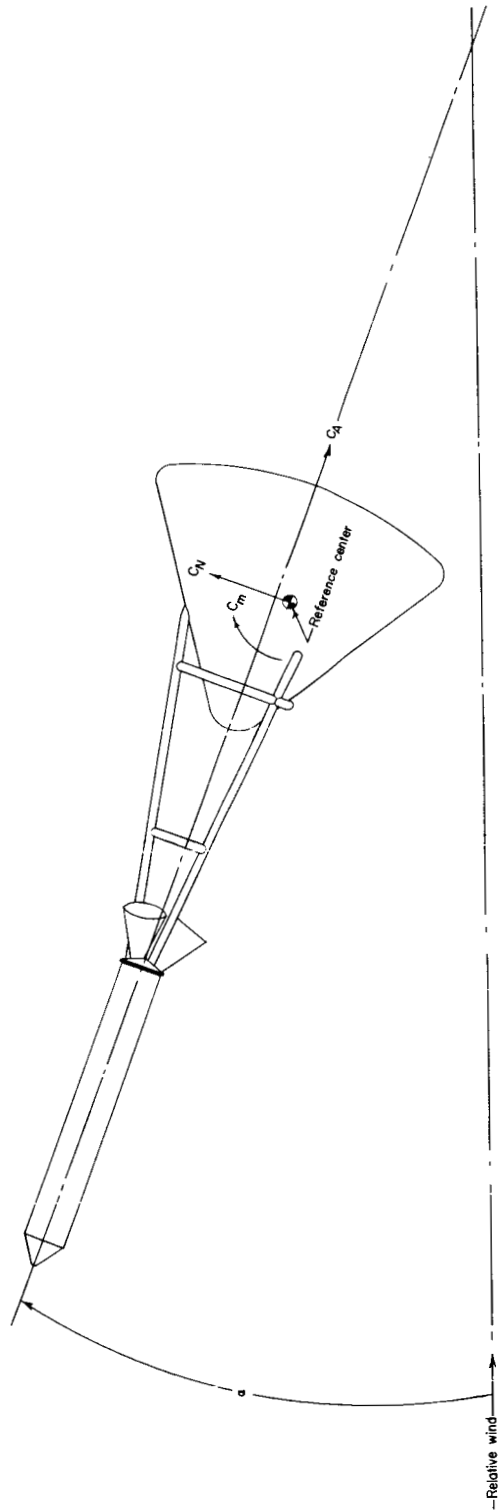
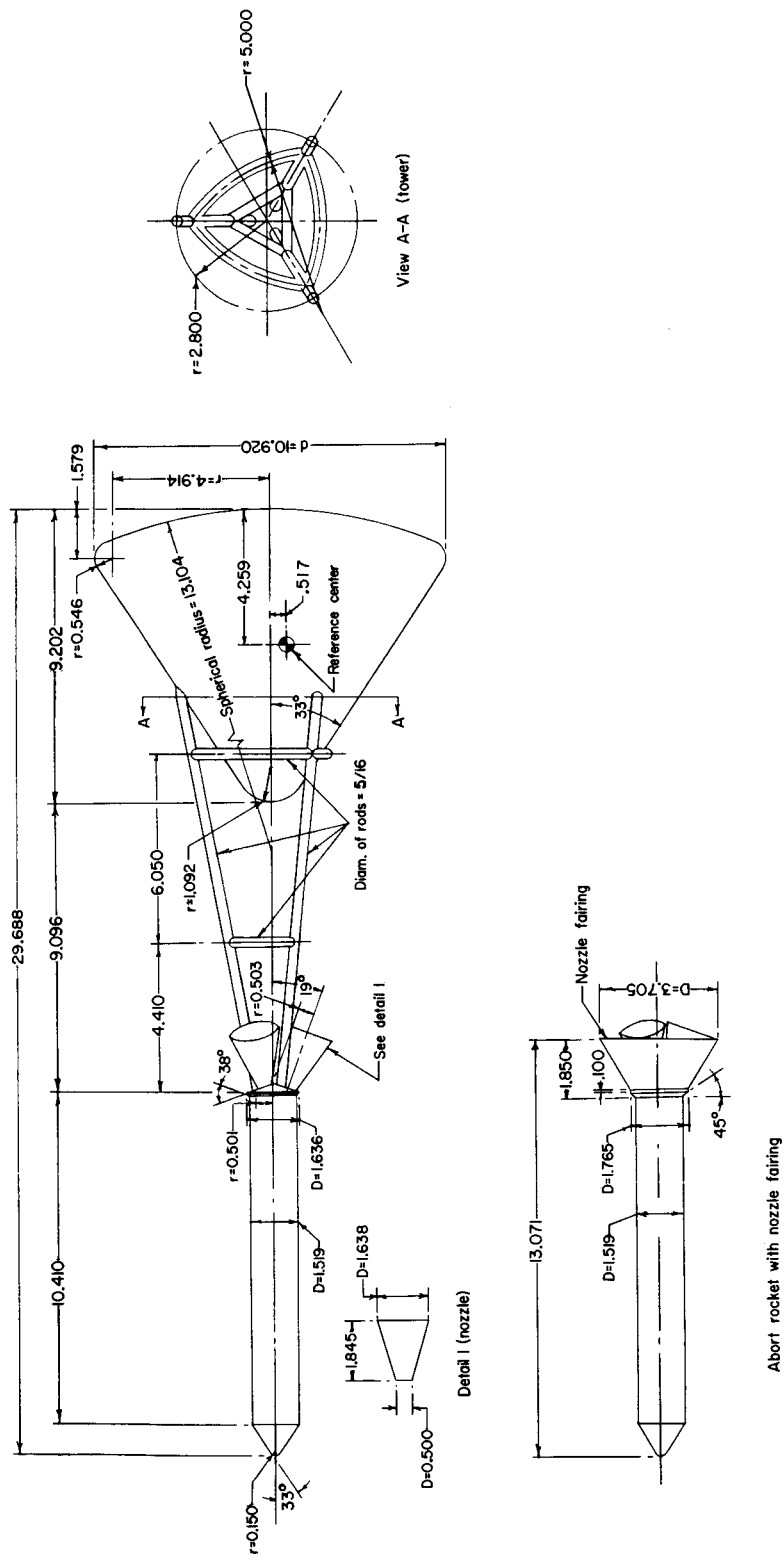
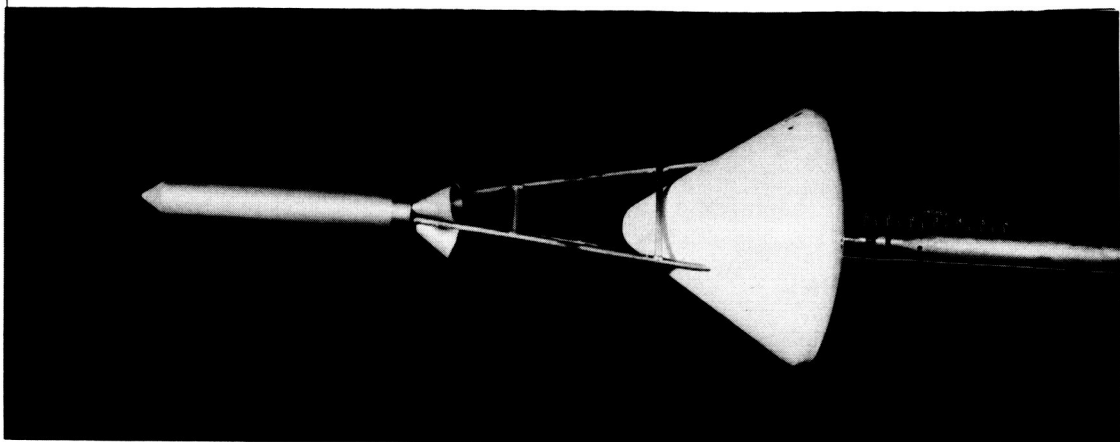


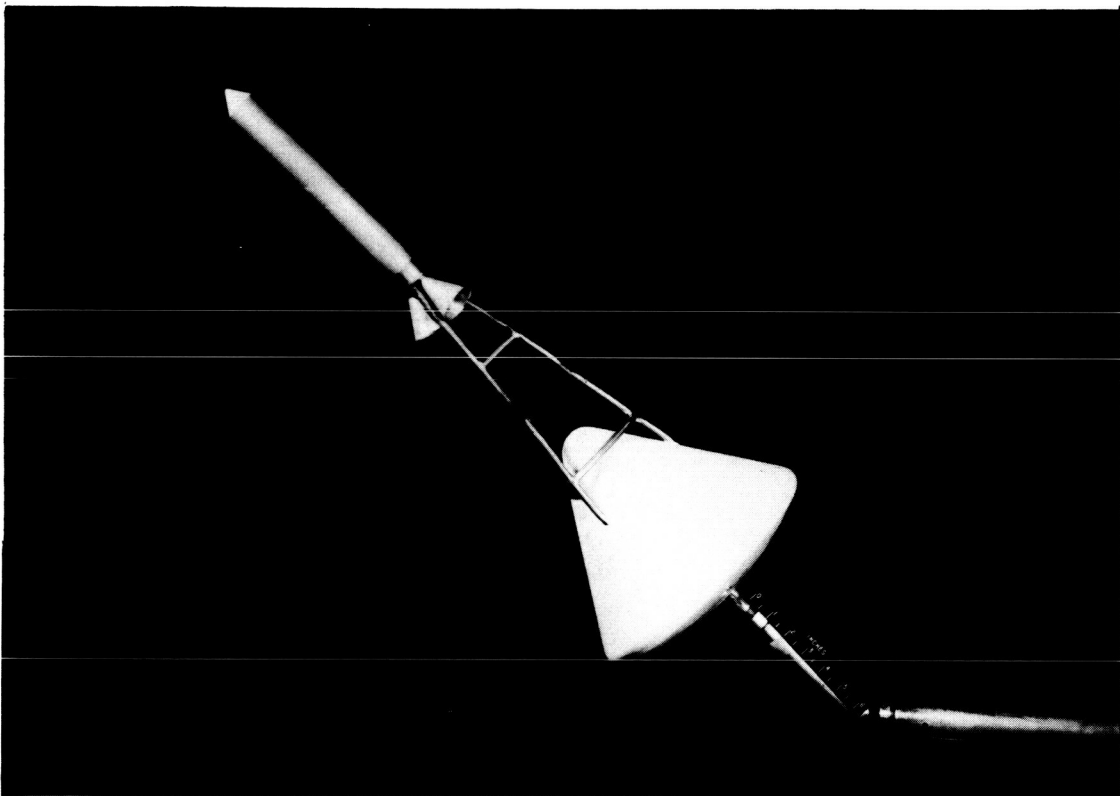
Figure 1.- Body system of axes. Arrows indicate positive direction.





$\alpha \approx -1^\circ$ to 24°

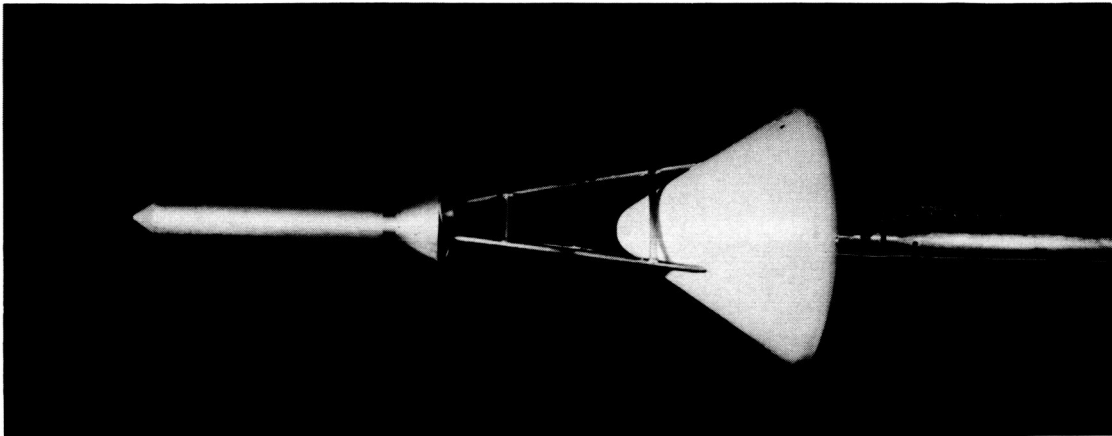
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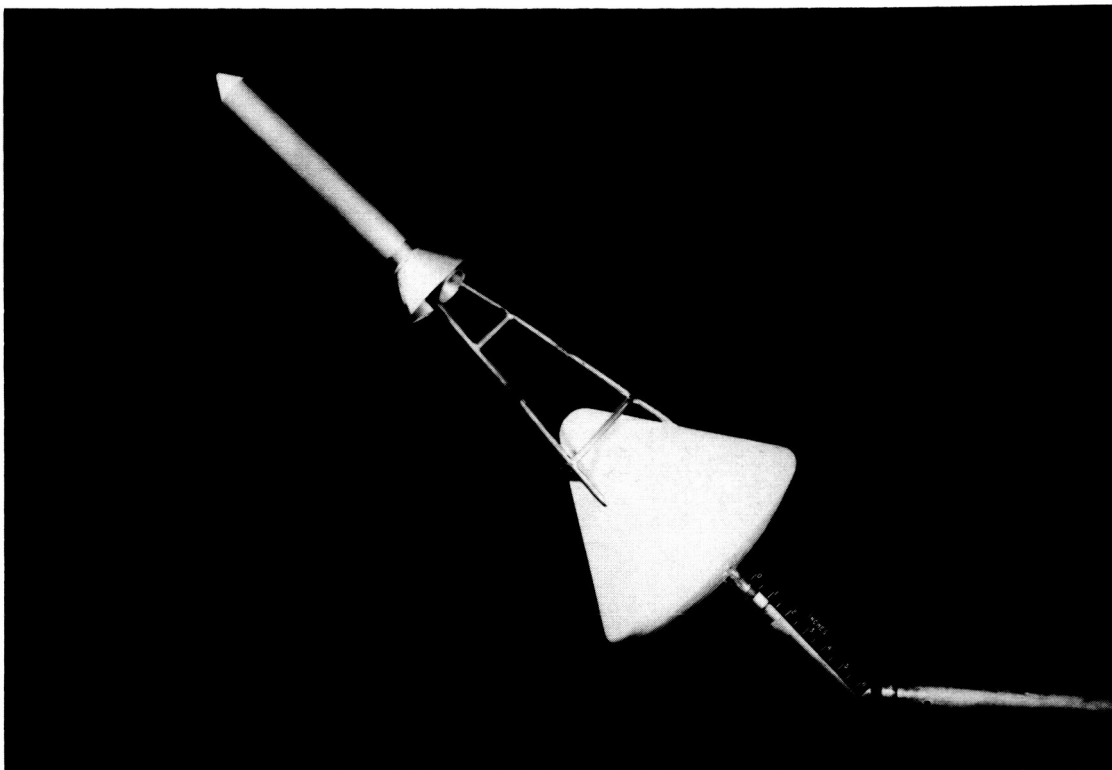
$\alpha \approx 24^\circ$ to 50°

(a) Model without nozzle fairing. L-61-286

Figure 3.- Model configuration and sting-support arrangements.

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L-61-283

 $\alpha \approx 24^\circ \text{ to } 50^\circ$

(b) Model with nozzle fairing.

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Figure 3.- Concluded.

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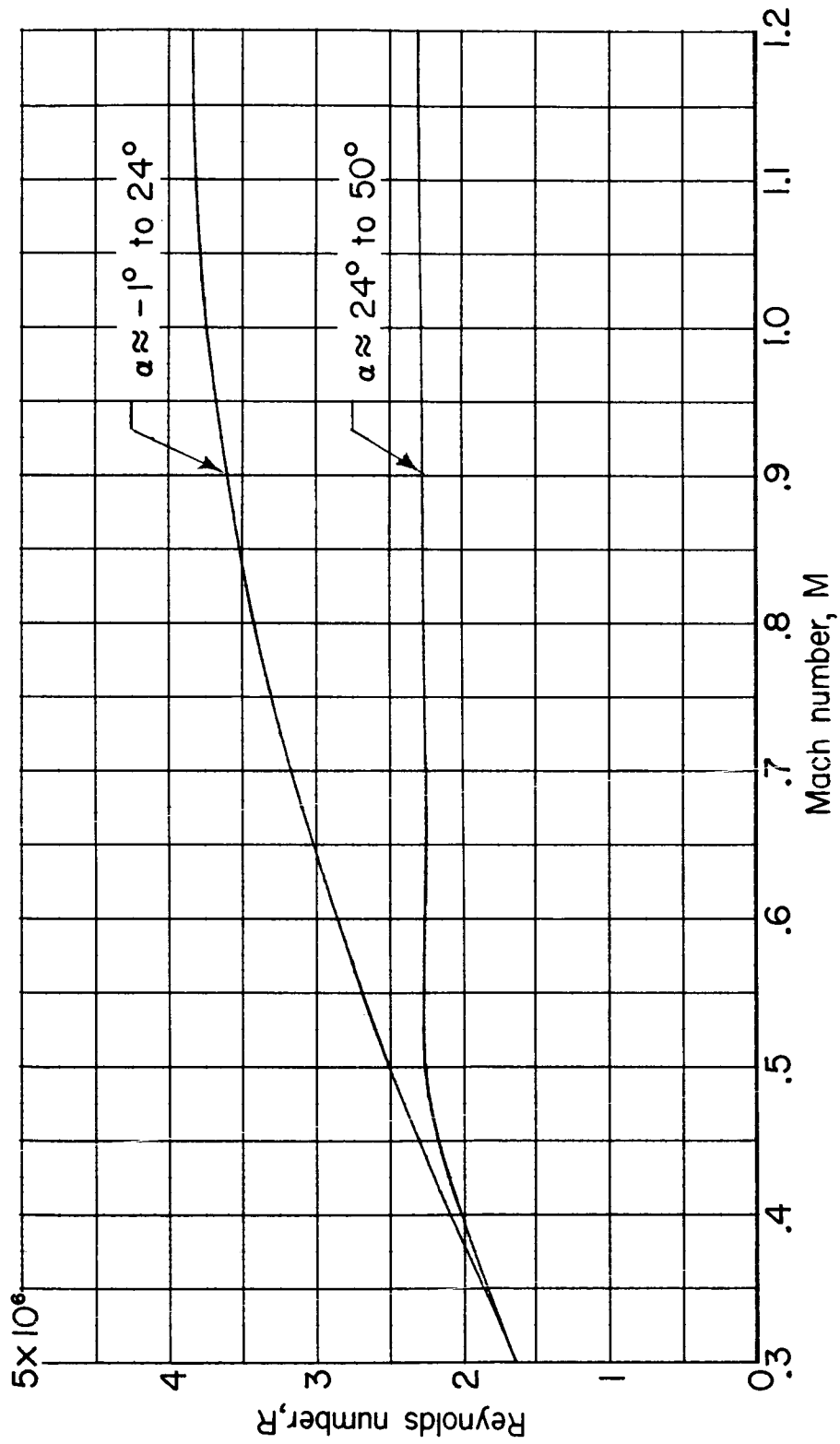
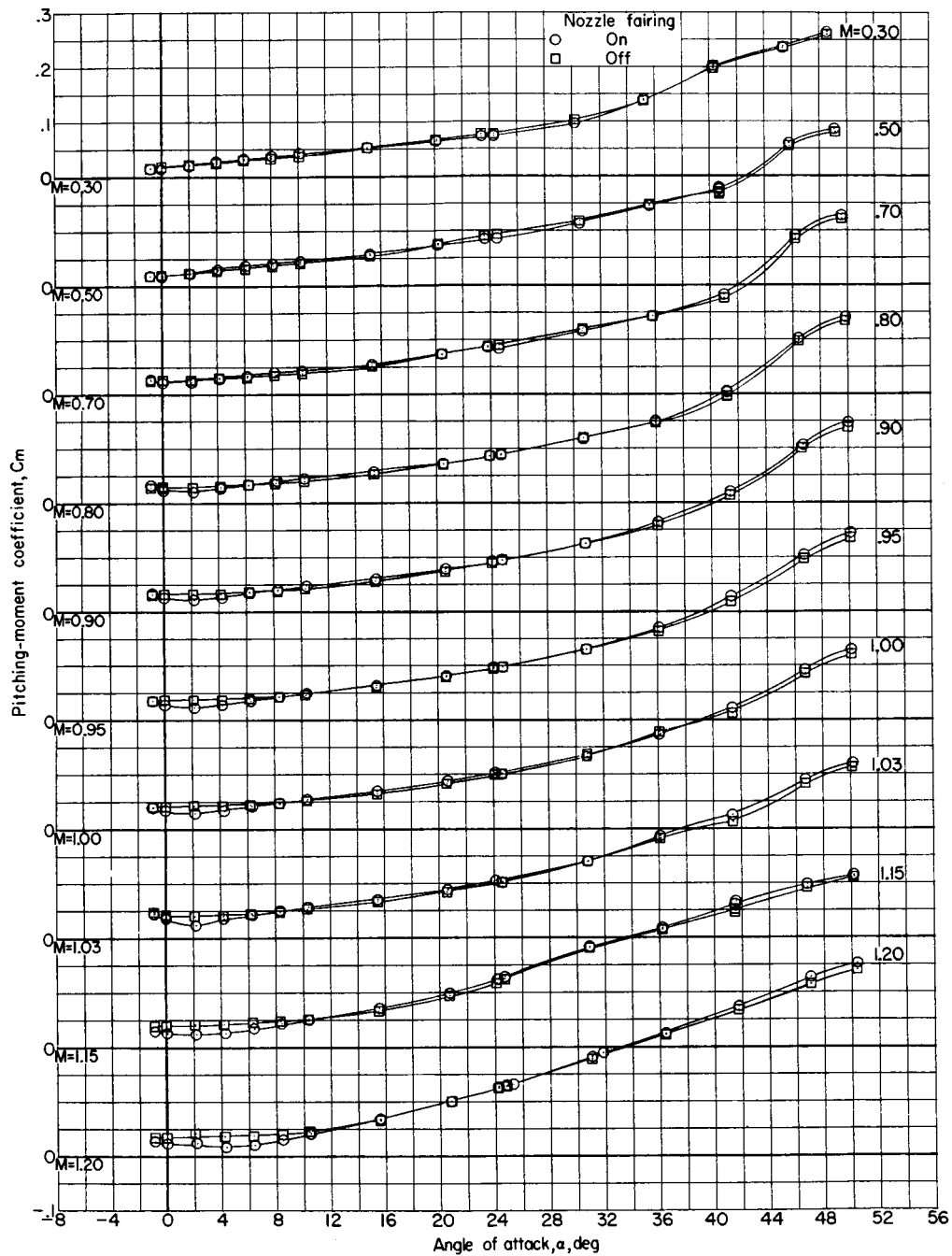


Figure 4.- Variation of Reynolds number, based on model diameter of 10.920 inches and free-stream conditions, with Mach number.



(a) Variation of C_m with α .

Figure 5.- Variation of static longitudinal aerodynamic characteristics of model.

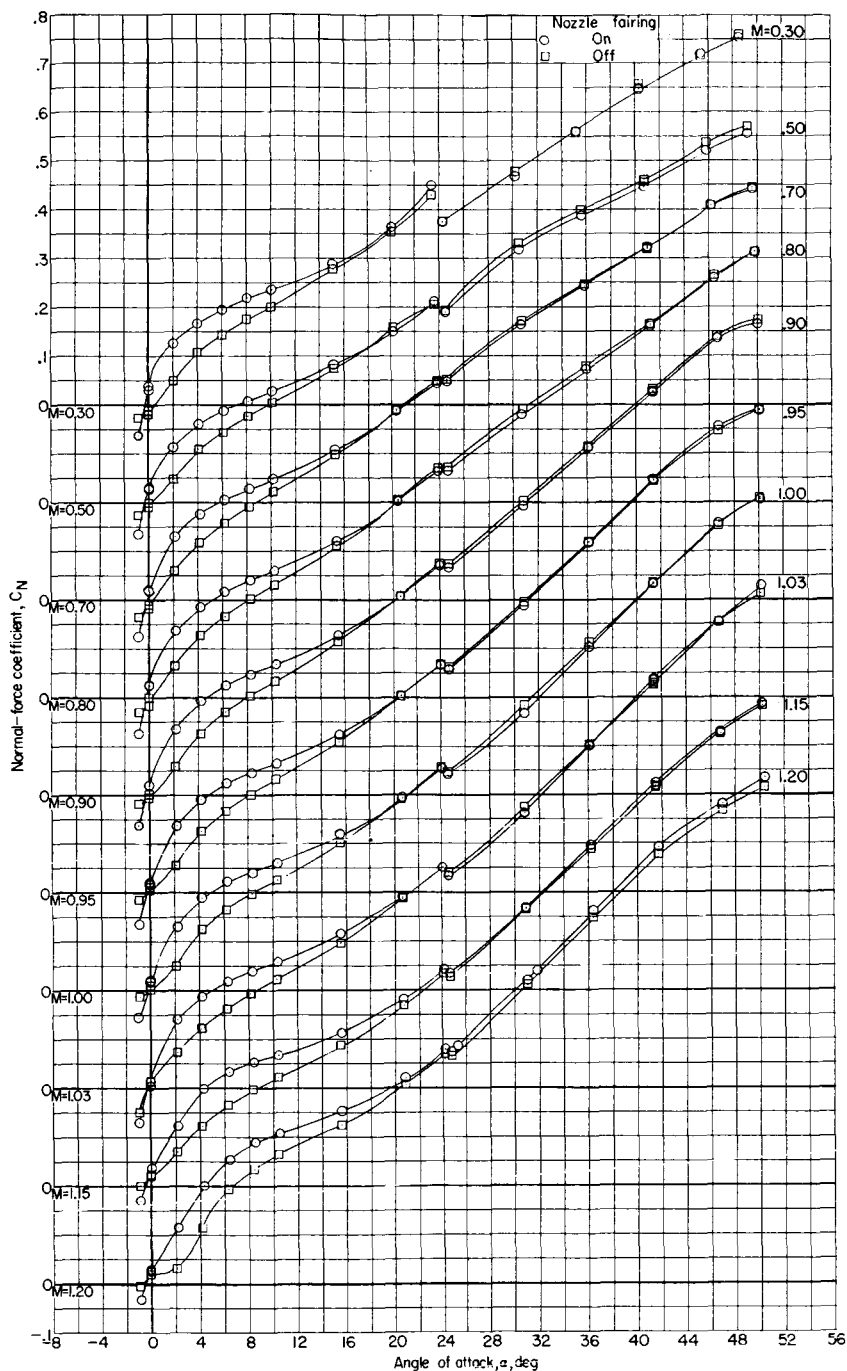
(b) Variation of C_N with α .

Figure 5.- Continued.

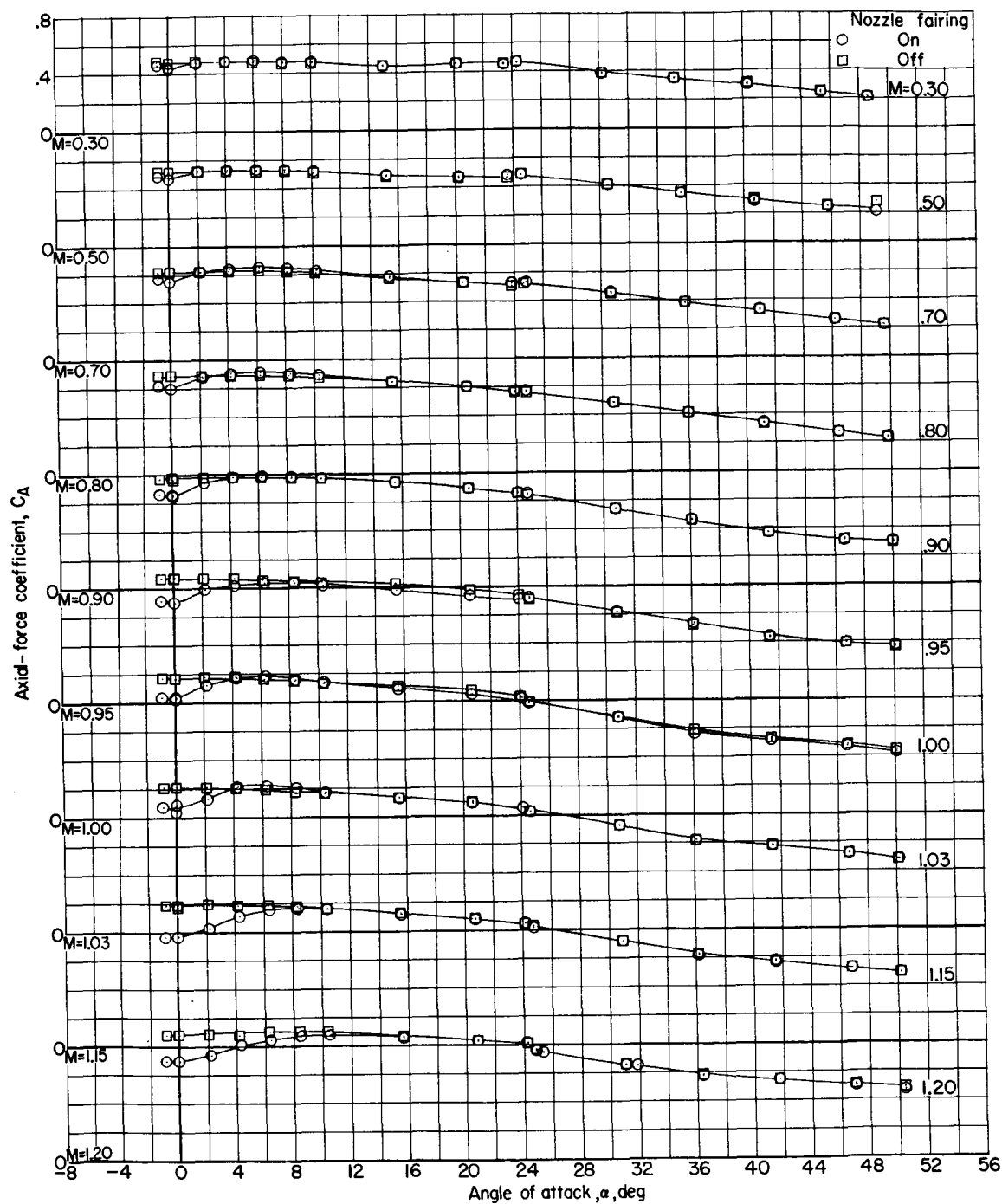
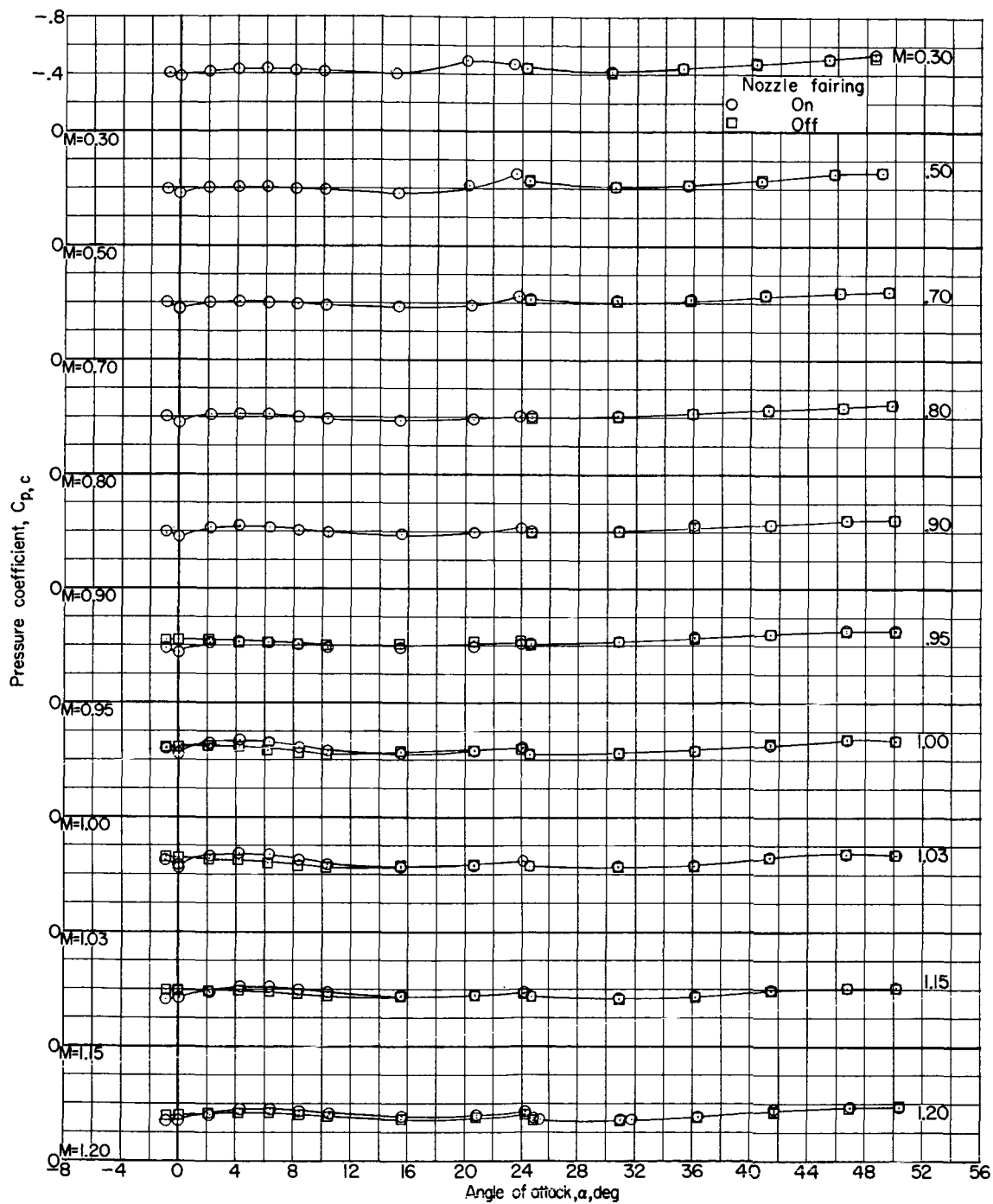
(c) Variation of C_A with α .

Figure 5.- Continued.



(d) Variation of $C_{p,c}$ with α .

Figure 5.- Concluded.

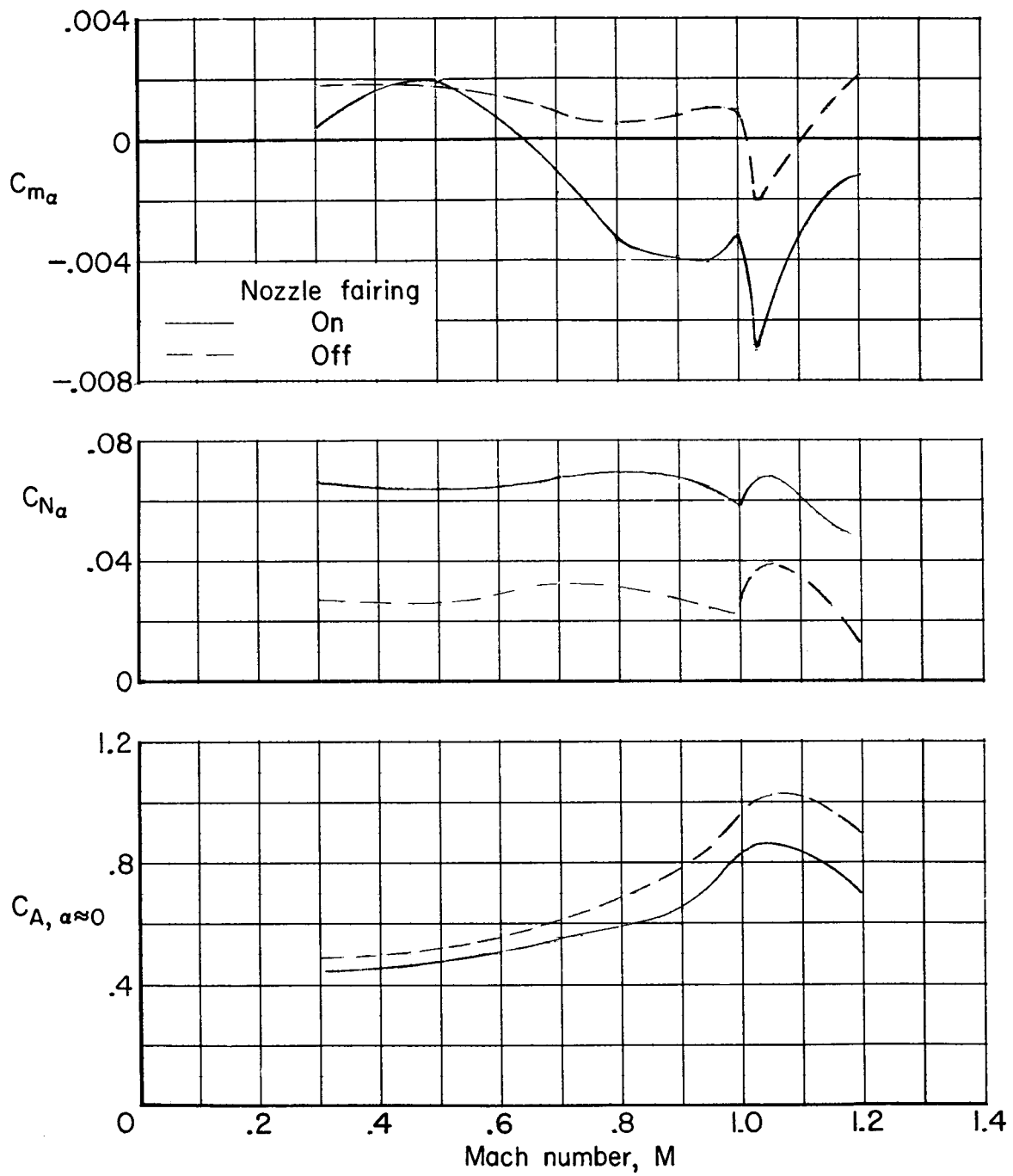


Figure 6.- Summary of static longitudinal aerodynamic characteristics of model.

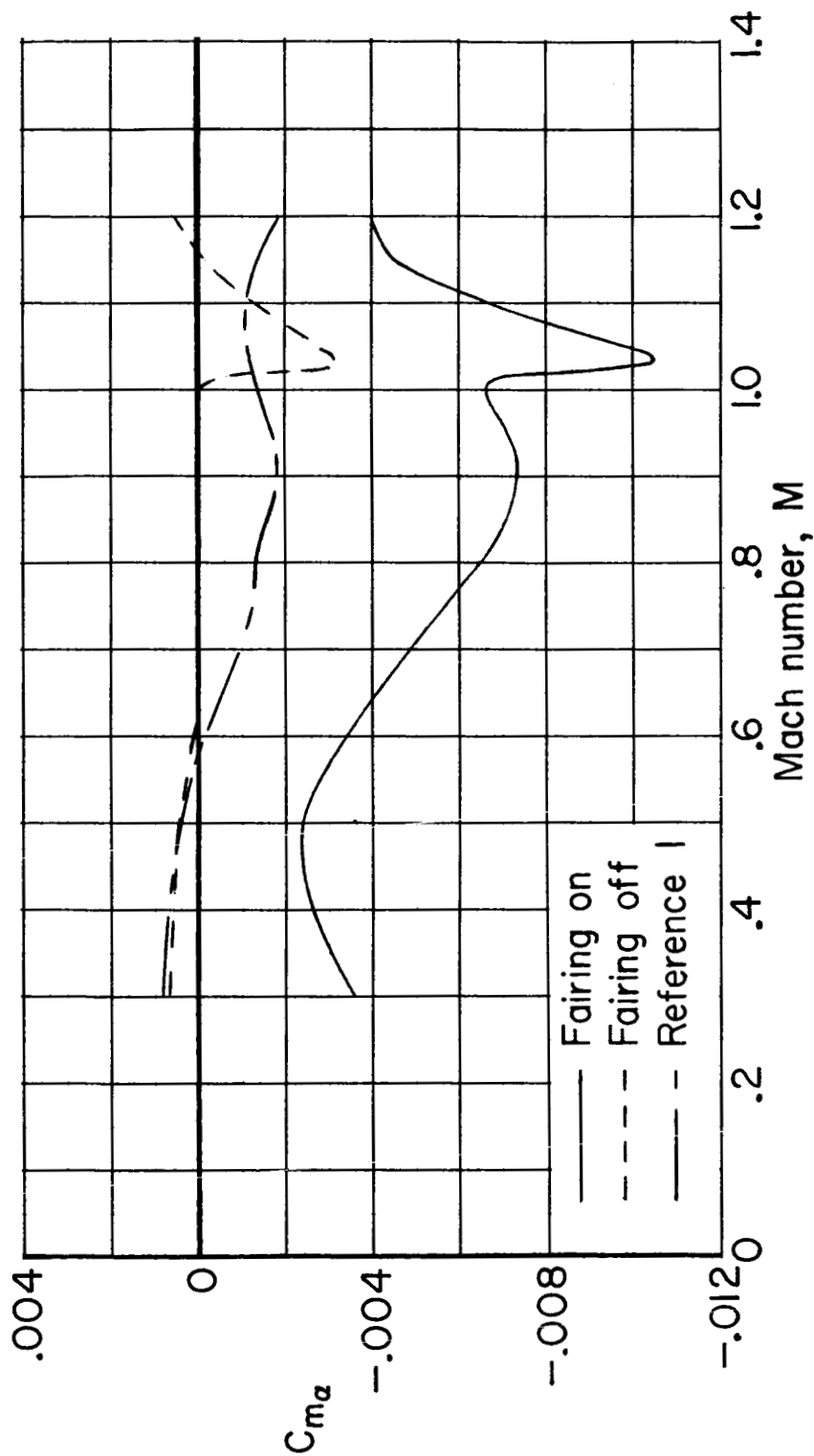


Figure 7.- Comparison of static longitudinal stability characteristics of test model with results for model of reference 1. Moment reference centers at $\frac{x}{d} = 0.426$, $\frac{z}{d} = 0$.